A Survey Method to Determine Plastic Rubbish in Port Phillip Bay, Part II, The First Six months

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Abstract

An experiment was started on 25th March 2016 on an urban Melbourne beach of Port Phillip Bay to count the plastic items that are being washed ashore every 24 hours along a fixed 35 m long section. The purpose is not only to quantify daily rubbish washed in from the bay but provide a possible method to determine the amount of plastic rubbish in the bay. This experiment is a horizontal sub-tide line survey which is performed only from the water up to the high tide line.

The purpose of the experiment is twofold and will provide new insights into the plastic within Port Phillip Bay. This experiment is only considering plastic below the high tide line and hence only what is being washed out of the bay every day. It does not address litter from other sources higher up the beach.

The first aspect is to monitor over 11 broad categories such as bottles, bags and food wrappers to identify types of litter plus 2 additional generic categories for other plastic items, those which are greater than 5 cm and those which are less than 5 cm. The ratio of the latter two can help provide insight on the breakdown rate of plastic in the water.

The second and more powerful aspect of this experiment is to enable some quantification of the amount of plastic in Port Phillip Bay. By surveying the same 35 m section of beach every 24 hours, as well as recording the on-shore wind vector, the amount of plastic being divulged on this beach section per day is determined for that wind vector. This can then be extrapolated around the bay perimeter for all on-shore wind vectors to reveal an estimate of how much plastic is being washed ashore every day.

Introduction

The requirement for monitoring the litter on our beaches has become more necessary as our population grows and our modern "convenient" life style results in increasing usage of disposable plastic items. With the ever improving understanding of the amount of plastic in our oceans and the consequences this has on us and the marine environment, it is important to find efficient ways to monitor this. Collecting good quality data is paramount to providing impetus for action to be taken to reduce the influx of plastic into our oceans[1].

In the large oceans, plastic litter can travel many thousands of kilometres. Identifying the origin can be near impossible, not only due to weather and currents, but due to international politics and cultures. These facets can make it very hard to bring the importance of the problem to the source.

Port Phillip Bay in Victoria is a nearly closed off large bay that offers a unique opportunity to undertake such a study. It has several river inlets that carry litter into the bay, but with only a narrow outlet to the greater ocean, most of the litter does not exit to the ocean. Instead it stays in the bay's waters or gets washed up onto a beach.

An experiment was started in March 2016 on an urban beach of Port Phillip Bay to monitor the plastic washed ashore every 24 hours on a fixed section of beach. The purpose of this experiment is different to other beach litter studies. Many surveys select a fixed sized area on a beach and count litter per square meter and extrapolate that over the whole beach. Another method used is a transect in which a fixed width section of one to two meters wide is surveyed from the water's edge all the way to the top end of the beach. This is an attempt to cover the different zones on a beach. It covers from the tidal zone at the water's edge, through the beach visitor zone at mid section, up to the wind catchment areas around bushes or fences at the top. These results are then extrapolated over the length of the whole beach. These methods provide information on the type litter on a beach at any one time. However they do not provide information on how much litter (type and quantity) is arriving on the beach.

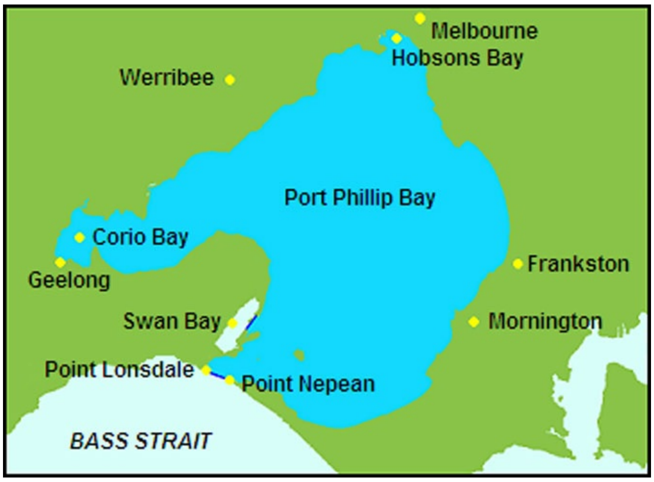

Fig 1 Map of Port Phillip Bay[2]

The issue is further complicated for urban beaches for two reasons. Firstly many local councils regularly sweep beaches with cleaning machines that sift the dry sand to remove most of the non sand items. If such cleaning has occurred prior to an audit, then the audit results will underestimate the litter. (These machines cannot get down to the tide line however as the wet sand clogs their workings.)

Secondly, there are people before work walking for exercise or walking their dog and many of these people casually pick up some litter when they see it. This too could skew any audit results to the underestimated side.

The experiment described in this paper is a horizontal tide line transect which is performed only along the water level up to the high tide line. A tide line only survey will not be affected by beach cleaning machines. The survey is also performed early in the morning and on a stretch of beach with low dog walking activity thereby removing chances of skewed data.

The purpose of the experiment is twofold and will provide new insights into the plastic within Port Phillip Bay. The first aspect is to monitor over 11 broad categories such as bottles, bags and food wrappers to identify types of litter plus 2 additional generic categories for other plastic items, those which are greater than 5 cm and those which are less than 5 cm. The ratio of the latter two can help provide insight on the breakdown rate of plastic in the water.

The second and more powerful aspect of this experiment is to enable some quantification of the amount of floating plastic discharged by Port Phillip Bay. Previous studies by the Victoria EPA[3] have shown that very little litter entering the bay escapes from it out into the greater ocean. By making an assumption that the bay over seasonal time spans is near steady state then as litter enters the bay from river out lets and other sources, it gets eventually washed up on the beaches. From surveying the same 35 m section of beach every 24 hours, as well as recording the on-shore wind vector, the amount of plastic being divulged by the bay is determined for that wind vector. In theory this can then be extrapolated around the bay perimeter for all on-shore wind vectors.

Related Work

A related experiment was performed in 1991 by Melbourne Water[4]. They released 1307 tagged items into the upstream waterways that drained into the bay. The items had a note for the finder so they could call and report the ID number, as well as when and where the item was recovered. Their study resulted in an estimated 4-5 million pieces of plastic entering Melbourne waterways per year. This was 23 years ago. Their findings showed most of the items recovered were found on northern and bayside beaches. A few as far south as Dromana but none further south from there. They found that approximately 50% of the litter released into the bayside beach turned up within the first 4 months. A further 8% was retrieved over the next 8 month period. Some were still retrieved after 21 months.

Experiment Design

The main survey was performed on a northern beach. Here a daily survey is to be performed for a full year. To date, six months of daily data have been collected.

The largest inlet to the bay is the Yarra River that flows through the middle of the Melbourne CBD then into the top of the Bay a few km later. This carries a lot of rubbish into the bay. Therefore the proximity of the north surveyed beach to the Yarra river inlet would mean the northern beaches are likely to received a higher rubbish loading than the further away southern shores. With this in mind a similar but shorter daily survey was carried out on a beach section on the southern shores. This was used to calibrate the calculations made from the northern shore. The same plastic items list was surveyed per day.

The north side section is shown with an X on Fig 2. A length of 35 m was selected for this section as on days when a heavy debris count washed in, any further length took too long to survey on a daily basis.

The southern section was at a beach at Tootgarook. Here a 50 m section of beach was surveyed

Fig 2 Location of Survey Area

Fig 3 Section of Beach

The area from the water's edge up to the high tide line was surveyed every morning for the number and type of plastic pieces washed upon it.

The items picked up were categorised into 14 types. Twelve were specific products and two were generic categories of plastic waste not identifiable to any one product type. The latter two types were listed as *less than 5 cm* or *greater than 5 cm*. Wave action eventually causes plastic pieces to break up into smaller and smaller pieces so the ratio of the greater than 5 cm to less than 5 cm is of interest for the bay as it may indicate how long plastic is staying in the water.

The wind direction and strength were recorded from a weather website[5] every morning as well. This was later separated into the on-shore and perpendicular to the shore wind vectors.

Port Phillip Bay is a bay with an area of 1950 km^2 and a perimeter of 264 km.

Data Calculations

Firstly, using a map of the bay, the coast line was divided into successive straight sections. In all there were 67 sections to span around the bay. For each section, the length was determined from the map scale and its orientation relative to north was tabulated. A minor linear adjustment was next made to ensure the total lengths of the sectors added up to the actual coast length of the bay perimeter. From this, components were calculated for each sector to ascertain the respective N,E,S,W facing directions and the component lengths. Summing these length components, the total distance of the bay coast facing each of the 4 compass points was determined.

Table 1. Length of Bay Shore facing each of the Compass directions.

South facing beach	86,091 m
North facing beach	87,827 m
East facing beach	77,731 m
West facing beach	84,882 m

Table 1 shows there are not a lot of variations between compass directions in net lengths of each of the beach facing directions.

Secondly, for the duration of the experiment, the wind speed and direction was recorded every day at the time of the daily survey. Wind seasonal variations are a large factor, hence the need to conduct this experiment for a year to cover multiple month-long term variations in wind vector days.

For all the wind vector days (wind-days) for the duration of the experiment, they too were separated into the components into each of the compass directions N,E,S,W. On shore winds were deemed the primary winds to blow rubbish on to a beach. Off shore winds or parallel-to-shore winds were deemed to not blow rubbish on to a beach. For example, a south facing beach with a south wind of 20 kph has a positive wind-day value of 20. A south facing beach with a N or E or W 20 kph wind vector has a zero value These are tabulated below for the duration of the experiment so far, till September 26^{th} 2016.

Table 2. Wind-days for the first 186 days of the experiment.

Wind-Day Direction	Value, kphDays
North wind vector day	1406
South wind vector day	263
West wind vector day	359
East wind vector day	121

Table 2 shows, the prominent winds for the experiment to date, are northerly winds. This is for the March through September months. These would be blowing litter on to the north facing beaches which are primarily at the south side of the bay.

The total wind-day data for an average year was determined from a second weather website[6]. This shows the wind strength and direction for an average per year for the last five years. From this, the annual wind-days can be calculated for each compass direction. These are shown in Table 3. This is used to extrapolate the survey data obtained for less than a year to a full year estimate.

Table 3. Annual wind-day for each compass direction for the last five years.

Wind-Day Direction	Annual Average Wind-day data, kph Days
North wind vector day	2415
South wind vector day	3129
West wind vector day	2041
East wind vector day	786

Thirdly, for each beach section surveyed, north and south, the total bits of plastic were tallied over the respective survey period 186 days for the north beach and 30 days for the south beach

For the first 186 days (6 months) the items of plastic washed up on the 35 m section of north beach are shown in Table 4.

Table 4. The count of plastic bits washed up on a 35 m section of a south facing beach for 186 days.

Plastic >5cm*	Plastic< 5cm**	Plastic Bags	Plastic Bait Bags	Straws	Bottle Tops	Bottles /Cans	Bottle Labels	Wrappers	Food Containers
8908	7205	467	44	378	345	47	88	3139	174
41%	33%	2.1%	0.2%	1.7%	1.6%	0.2%	0.4%	14.4%	0.8%

Balloons & strings	Butts	Polystyrene Bits	Syringes	Total Pieces
196	384	383	5	21,761
0.9%	1.8%	1.8%	0.02%	

In Table 4, the percentages of each category are shown for comparison. The categories of plastic >5cm, plastic < 5m and wrappers are the three largest types and make up 89% of the count.

The total counts for each beach were then divided by the respective beach length surveyed and the number of onshore wind days for that beach to arrive at a value of the pieces of plastic per meter per wind day. These are shown in table 5.

Table 5. Determining pieces of plaster per meter per wind-day on a beach

Beach Location	Total pieces counted	Beach Length surveyed	On shore wind-days	Pieces/meter/wind-day
North, 186 days of data	21,761	35	263 South wind-days	2.5
South, 30 days of data	1452	50	270 North wind-days	0.11

As can be seen in Table 5, the number of plastic items washing ashore on a southern beach is significantly less (4%) than a northern beach.

Averaging the north and south end beach items per meter per onshore wind day gives a value for the west and east facing beaches of 1.2.

Finally an estimate of the total number of pieces washing out of the bay for each of the four compass directions can be calculated and is shown in Table 6. .

Table 6. Estimation of the amount of plastic Items washed ashore over one year.

Wind Direction	Beach Length Facing wind, m	Wind Days, kph day	Items per m per WD (Onshore)	Extrapolated Plastic items washed ashore per year
N wind	87,827	2415	0.11	22,693,895
S wind	86,091	3129	2.4	636,934,311
E wind	77,731	2041	1.2	214,071,342
W wind	84,882	786	1.2	75,509,876
			Total	949,209,424

Table 6 predicts an astounding 950 million items of plastic are washed out of our Port Phillip Bay per year. As mentioned previously this calculation is heavily influenced by the predominance of the northerly wind vector days over the experiment duration so far. See the Discussion section for further comments.

Broken down into the 14 categories, the model predicts the values for each category as shown in Table 7.

Table 7. Projection of the composition of the plastic items washed ashore over one year.

Plastic>5cm*	Plastic<5cm**	Plastic Bags	Plastic Bait Bags	Straws	Bottle Tops	Bottles/Cans
388,564,751	314,280,314	20,370,424	1,919,269	16,488,266	15,048,814	2,050,128

Bottle Labels	Wrappers	Food Containers	Balloons & strings	Butts	Polystyrene Bits	Syringes
3,838,538	136,922,402	7,589,837	8,549,471	16,749,985	16,706,365	218,099

Discussion

The above uses an average of the north beach and the shorter term south beach data to estimate the pieces/m/wind day on the western and eastern beaches. The annual wind data from Table 3 shows there are approximately three times more westerly wind days are as easterly wind days. This would indicate more items would be expected to be washed out on the eastern beaches. Figure 4 shows modelling results from the Victoria EPA[7] of the dispersion of plastic items washed out of the Yarra River. The graphic as expected shows a heavy bias to pieces ending up on the north and eastern shores.

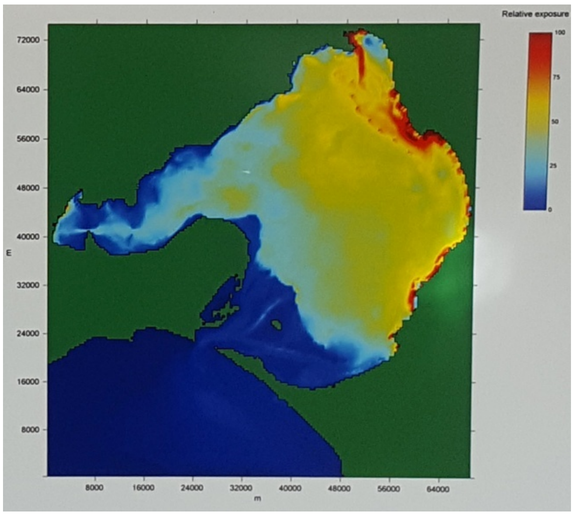

Fig 4. Predicting Plastics Dispersed from Yarra River

The tide line survey model used in this experiment should be calibrated to provide more refined results by repeating the same full experiment at each of the compass points E, S, and W around the bay. This would involve a daily commitment for a year, meaning many hours of work and possibly beyond the scope of asking other volunteers to perform this.

This survey so far, only covers the first 6 months of a year. It is expected once the next 6 months of the data for the year has been entered, a different result may be obtained with the spring and summer months (August-March) potentially bringing more southerly wind days offsetting the large northern bias recorded so far.

The ratio of the smaller than 5cm to greater than 5 cm pieces of plastic is 65%. This could indicate that most of the plastic in these categories is not broken down to small bits as would be expected to happen if they were in the water for a long time. This would indicate the plastic bits are washing ashore sooner rather than later.

Assuming the bay is near steady state year on year, then this count estimation in Table 7 indicates the amount of plastic washing out of the bay every year would expected to be similar to the amount washing into the bay.

The breakdown of the types of plastic collected show that approx 80% of the items observed are made up of only 3 of the 14 categories. Pieces greater than 5cm, those less than 5 cm plus food/candy wrappers are the predominant items. Items in the greater than 5 cm and less than 5 cm are typically pieces of clear soft plastic film from food shrink wrap, stretch wrap and bag remnants. Many hard pieces also wash ashore. These include nurdles and broken up larger fragments.

A question could be asked; why was the plastic drink bottle count so low with the high prevalence of littered drink bottles in Victoria? There are a few reasons for this. Plastic bottles are made from PET, a material that sinks in water. If the cap of the bottle is not screwed on, the bottle can sink to the bottom of the bay. Another reason is that bottles are light weight and quite large. They catch the wind and easily roll further up the beach out of the tidal zone.

The maximum number of plastic items picked up in one day off the 35 m section was 2793 pieces after a strong southerly wind for two days. This would be an alarming number in most people's perspective and shows the importance of measures needed to curb this finding.

Conclusions

The amount of floating plastic washing out of the Port Phillip Bay every year is alarmingly high. Over 950 million items are estimated through the above model. The model could be refined with sampling points in the other compass directions to provide more accuracy.

The potential harm to wildlife with a great number of pieces of plastic in the bay and on its shores is significant. Small pieces of plastic such as fragments as well as raw nurdles pose threats. The greater the opportunity for wildlife to mistake plastic as food the greater is the threat of harm.

The majour contributors cited thus far are plastic film, plastic bags, plastic wrappers and smaller broken pieces of hard plastic.

The continuation of the experiment to complete one year's worth of daily data will provide more accuracy to the model. This will encapture all the seasons with their seasonal wind directions to provide a fuller overall picture. This will be complete in Mar 2017.

Here in Australia, where we claim to be a cleaner country than many others, this experiment has predicted an abysmal number. This reinforces the conclusion of the 2106 Federal Senate inquiry that URGENT action needs to be taken to protect Australian waters from plastic waste pollution. Providing more waste bins, more frequent bin emptying and extra clean ups is not enough. Stopping the plastic from getting into our waterways in the first place is the only solution. This requires government intervention with more anti littering programs to educate the public, financial incentives to reduce littering such as a container deposit scheme, and encourage recycling. It will be necessary to also work with industry to incentivise their reduction of plastic waste and to reduce disposable plastic packaging and the use of disposable plastic items.

About BeachPatrol Australia[8].

This is a volunteer group based in Melbourne Australia. It is made up of over 1700 volunteers concerned about litter on the beaches. Currently the organisation is divided into 21 groups. Each group is responsible for one post code along the bay shores. The groups pick up litter from the beaches in their post code once a month and record basic collection data on the website. Each group's data is recorded as well as a running summation for the groups as a whole.

References

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